Energy, Mines and Resources Canada

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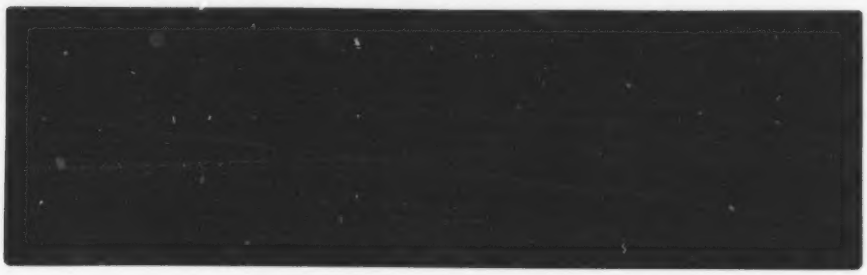
Canada Centre for Mineral and Energy Technology

Centre canadien de la technologie des minéraux et de l'énergie

Coal Research Laboratories

Laboratoires de recherche sur le charbon



Canada

THE DESIGN AND TESTING OF PROGRAMMABLE LOGIC CONTROL SYSTEMS FOR ELECTRIC CABLE SHOVELS

FINAL REPORT
BY:

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Work on the project was conducted under the auspices of the Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources Canada.

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1.0 EXECUTIVE SUMMARY

This report is based on the design and field testing of a programmable logic control based system for two electric cable shovels at the Bullmoose Mine in Tumbler Ridge, British Columbia.

An operator friendly Programmable Logic Controller (PLC) system was installed on the shovels. The inputs and software were developed by Bullmoose electricians to control the lubrication system and monitor shipper shaft bushings and electrical motors. During the field test the PLC performed effectively and the alarms were reliable and timely.

Grease consumption in the lubrication system has not been reduced but it is now being supplied to all the required areas of the shovel. There were several incidents where the PLC signalled early warning of overheated shipper shaft bushings and motors. The early detection of these problems resulted in substantial cost savings.

The project was completed on time and on budget. Early cost benefit calculations indicate that the installation cost of the PLC has already been realized in cost savings from the early warning of major problems.

Due to the success of this project, future expansion of monitoring and control functions are planned. Also, it is planned to install PLC's on all of the shovels at the Bullmoose Mine and possibly the drills and haulage trucks.

1.1 RESUME

Cette report est bassé du design et des essais de la systeme programmable logic control pour deux pelles electriques de la mine de charbon Bullmoose à Tumbler Ridge, Colombie Britannique.

Un system c'est ne pas difficille, le Programmable Logic Controller (PLC), pret s'installer dans les pelles élétriques. Le péripheriques et la program sont concevent par les élétriciens pour la controle des system lubrification et éléctrique et les baque shipper shaft. Vers les temps essais, la PLC executer éfficacement et les alarms sont digne de confidence et à propos.

La consumption de la graisse c'est ne pas décrôite mais il est l'alimentation du tout les places sur la pelle. Il'ya plusieurs fois quand la PLC fait le signal prématurément ce devenir surchauffé de les baque shipper shaft et les moteurs. La détection prématurément de les problems resulter plus-que la économie.

Cette project son complete ponctuel et d'un budget. Les calculations tôt indiquer le cout de l'installation des PLC été un drai la économie pars la détéction prématurément des les problems majeur.

Parce que le succes de cette project, le agrandissement à l'avenir de les fonctions de près et les PLC sur touts les pelles, les trépans et les camions de charbon Bullmoose.

2.0 INTRODUCTION

At the Bullmoose Mine in Tumbler Ridge, British Columbia, a truck/shovel system is the major mode of overburden removal. For the shovels to operate effectively proper lubrication must be maintained at all times. Historically, the lubrication system on shovels have been a high maintenance area. The systems in place are crude and often unreliable and the methods available to monitor them do not incorporate available technology. Equipment manufacturers have been slow to respond to this problem. Also, there are no suitable methods available to monitor electrical motors and bushings on our mining shovels. Problems associated with lube system malfunction and premature motor and component failure often result in major costs to mining companies.

More reliable and flexible systems are presently available for monitoring and operating stationary equipment. This type of equipment is monitored by Programmable Logic based systems.

The development and installation of an operator friendly Programmable Logic Controller (PLC) on a shovel would provide the mining industry with a reliable and flexible tool for monitoring the performance of problematic areas of the shovel. This system has the potential of increasing the reliability and availability of the shovel by reducing the trouble shooting time. Component life will also be extended if problems can be detected before damage has occurred. This will lead to increased productivity for the shovel and reduced costs due to extended component life.

The objective of this project is to design and field test Programmable Logic Controller (PLC) based systems for two of the electrical cable shovels used at the Bullmoose Mine.

The PLC system is equipped to monitor and control the lubrication system and monitor the condition of electrical motors and shipper shaft bushings. This system provides a display of data and condition (lack of grease, unlubricated area, abnormal temperature) in the shovel operators cab on a plasma display.

The PLC systems have been field tested over a period of six months for one shovel and four months for the other shovel. The field tests have spanned both summer and winter operating conditions. The data from these field tests have been evaluated to determine the effectiveness and reliability of the PLC systems. The installation of the PLC, results from the field testing, cost benefits and future expansion are the subject of this report.

3.0 TECHNICAL DISCUSSION

3.1 Design

The following is a discussion on the design and installation of a Programmable Logic Control (PLC) system for electric cable shovels.

The PLC systems were installed on two of the electric cable shovels (P&H 2100 BLE) at the Bullmoose Mine. The PLC system consists of a processor, a power supply, input/output cards and a plasma display. The hardware is based on the

Allen Bradley PLC-2 system. The Electrical Department at Bullmoose assembled the PLC and attached the necessary inputs to produce a control system on the shovels. Then the software was developed to implement the monitoring programs. The system can monitor:

1. The Lubrication System
2. The Shipper Shaft Bushings
3. The Swing Motor Temperatures
4. The Crowd Motor Temperature
5. The Hoist Motor Temperatures
6. Motor Field Shunt Trip

The lubrication system alarm is based on the pressure of the lubrication lines. In the motors and shipper shaft bushings the temperature is monitored via Resistance Temperature Devices (RTD). The critical pressure of the lubrication lines and temperature for the motors and bushings is calculated from operating information. An alarm is programmed to annunciate once the critical pressure or temperature is reached. The alarm message will also show on the plasma display in the operators cab. The audio alarm can be reset by the operator but the plasma display alarm must be reset by the electrician once the affected area has been checked. The affected area will not automatically shut down the shovel but it is up to the operator to contact the electricians immediately and let them know about the alarm. The PLC does have the capability to shut down the shovel once an alarm is given however, this hasn't been required as operator response is satisfactory.

In December, a field shunt trip program was added to the PLC. This provides the crowd and swing motors with protection from field currents when the shovel is off. A problem in the P&H control frame causes the fields on the motors to remain on maximum while the shovel is shut down and the blowers are off. This has caused the motors to overheat and resulted in extensive damage and costly repairs. The shunt trip program monitors if the shovel is off and if a field current continues to flow. When these two conditions are met the PLC will turn on an output to shunt trip the field's main supply breakers.

The PLC system scans the shovel information every 15 milliseconds and updates the inputs and outputs. The plasma has the storage capacity for 100 lines of alarm messages. Therefore, there is adequate capacity for future programming and an increase in the monitoring and control functions. The scan time may increase slightly as new functions are added to the system.

A PLC training module is located in the electrical shop. This familiarizes shovel operators with the PLC and gives them a chance to see how it works. The programming and test work is also done on the training module, by Bullmoose electricians, before being used in the field.

Schematics of the lubrication system, field breaker shutdown and resistance temperature devices used to monitor the motors and bushings can be seen in Figures 1 to 4. There is also a schematic of the PLC components.

3.2 Field Testing

The PLC system has been installed on unit number 2303 and 2304 electric cable shovels. Both of the systems installed on these shovels monitor the lubrication system, motors and bearings listed previously.

The field testing continued from June 1989 to January 1990 for 2304 shovel and from October 1989 to January 1990 for 2303 shovel. It consisted of keeping a special log book for 2303 and 2304 shovel alarms (See Appendix A). The purpose of the log book was to record the nature of the faults annunciated by the PLC unit. For every alarm the following information was recorded; the fault, the affected area, the nature of the problem and the work order number for the job so parts costs could be tracked.

The log books for each of the shovels were analyzed at the conclusion of this project. They indicated the problems encountered, how they were solved and the number of times the alarms averted motor damage, component failure and downtime.

The PLC systems were field tested in both summer and winter operating conditions. There was no indication that the colder weather affected the operation of the PLC system and the results from the field testing were very favorable.

There were a few false alarms in the first stages of field testing. Once minor alterations were complete the PLC systems performed reliably.

Due to these results a PLC system was added to a third shovel at the Bullmoose Mine.

Operator response to the PLC system has been improving as they become more familiar with it. The training department has also been involved with making shovel operators more aware of the PLC system and its benefits. On more than one occasion the plasma alarm and quick reporting of the alarm by the operator has prevented major component failure. The PLC system has also been an effective trouble shooting tool.

Overall, the results of the field test indicate that the PLC system monitors lube system pressures and motor and bushing temperatures as expected. More reliable performance from the lube system ensures that grease is delivered to all parts of the shovel. The field testing also indicated that monitoring the motor and bushing temperatures helps to warn of a problem before any major damage occurs. The PLC also reduces trouble shooting time by accurately pinpointing the problem area.

3.3 Cost Benefits

The cost benefits of installing the PLC's on the shovels have been many. The lube system is working more effectively, major components and motors have been saved from damage on several occasions and trouble shooting has become more efficient. This results in reduced shovel downtime and increased productivity.

There have been numerous lube alarms on both of the shovels in the early stages of the PLC installation. The typical faults consisted of broken grease lines, air leaks, low grease in tanks and pressure switch failures. By investigating each of these faults and diagnosing the problems the lube systems are now working more effectively and the number of alarms has decreased. Grease consumption has not been reduced but it is now being delivered to all of the required areas instead of leaking all over the shovel causing big clean-up jobs.

There has been two occasions on the 2304 shovel when the PLC has annunciated an alarm for overheating shipper shaft bushings. The shovel operators quickly reported the alarm and maintenance personnel investigated. The shipper shaft bushings were found to have no grease and when they were regreased the alarm cleared. This saved an early breakdown on the bushings on both occasions. Shipper shaft bushings cost approximately $50,000 dollars to change out, therefore, the PLC has saved $100,000 in repairs with these two incidents. This does not include the loss of production due to shovel downtime as shipper shaft bushings usually take about seven to ten days to replace.

The PLC has successfully warned of an overheated crowd motor. Once the alarm was annunciated the crowd motor was checked and was found to be running hot. The problem was found when checked. It was determined that the blower was on backwards. This incident prevented the

early demise of a crowd motor armature. The cost to repair and change out the crowd motor is approximately $15,000. Downtime for the shovel can range from one to eight days, depending if a spare is available.

Since the PLC's have been installed there have been no major repairs required to the areas being monitored. Also, the alarms have been effective in the early warning of problems so they can be corrected before any damage occurs. This has saved approximately $115,000 in repairs, not including loss of production during downtime. The two PLC units cost $100,000 to assemble, design and install. Therefore, they have paid for themselves over a very short period of time and similar cost benefits are expected in the future.

There is no conclusive evidence, at this point, to indicate if the PLC's increase component life. For, example the life of a shipper shaft bushing is 10,000 hours so we will have to analyze this again once the PLC's have been on the shovels for a longer amount of time.

3.4 Future Expansion

Due to the success of this project, Bullmoose Operating Corporation has future expansion plans for the use of PLC's on mobile equipment.

3.4.1 Shovels

The first step will be to install a PLC on the remaining shovels at Bullmoose Mine. Once

3.4.3. Trucks

A PLC could also be added to new haulage trucks. Its main function would be to control engine rpm and monitor components. This would ease trouble shooting and reduce costs by increasing component life.

4.0 CONCLUSIONS

Bullmoose Operating Corporation designed the inputs and software to implement a Programmable Logic Controller (PLC) system for two of the electric cable shovels at the Bullmoose Mine. The PLC system was designed to control the lubrication system and monitor the condition of the shipper shaft bushings and electrical motors.

The PLC was field tested and evaluated. They were determined to be operator friendly and working effectively. Some adjustments were made in the initial phase of field testing to fine tune the system. Presently, the alarms are very reliable and have prevented major component and motor damage on several occasions. The lubrication system is also working more reliably. Although grease consumption has not been reduced, it is now being delivered to all areas of the shovel and this was the aim of the project.

The cost benefits from the installation of PLC's have been substantial. The PLC has signalled problems

before any damage occurred to motors or bushings which has saved $115,000 in repairs, not including potential loss of production due to downtime. There is also the cost benefit in the form of reduced trouble shooting time. The two PLC units cost $100,000 to assemble, program and install. Therefore, they have paid for themselves over a short period of time and similar cost benefits are expected in the future.

The project was completed on time and on budget. There have been no variations from the original statement of work. Problems encountered during the field testing were manageable and have been corrected so that the PLC's are operating reliably.

Future expansion is planned for the PLC systems due to the success of this project. There will be a PLC installed on all four of the electric cable shovels at the Bullmoose Mine. Also, more monitoring functions will be added as they are needed.

APPENDIX A

STATEMENT OF WORK

CONTRACT NO: 23440-8-9267/01-SQ

TITLE: DESIGN AND FIELD TESTING OF A PROGRAMMABLE LOGIC BASED SYSTEM FOR LUBRICATION AND ELECTRIC MOTOR MONITORING ON AN ELECTRIC CABLE SHOVEL.

OBJECTIVE:

On behalf of the Department of Energy, Mines and Resources, CANMET, Coal Research Laboratories shall undertake the design and field testing of a programmable logic controller system for an electric cable shovel.

BACKROUND:

Truck/Shovel systems comprise the major mode of overburden and ore handling at Canadian surface mines. A major requirement of effective operation and maintenance of these shovels is that proper lubrication be maintained at all times. Historically the lubrication systems on most operating shovels are a high maintenance area. These systems as presently designed are often unreliable. The methods available to monitor them do not reflect the technology available in the rest of the shovel. Problems associated when these systems malfunction are often reflected in major costs to mining companies.

Equipment manufacturers have been slow to respond to this problem. Their lubrication systems are not on the leading edge of the technology available. Also, there are presently no suitable methods of monitoring the operating parameters of electrical motors on mining shovels.

The development and installation of an operator friendly Programmable Logic Controller (PLC) on a shovel would provide the mining industry with a reliable and flexible tool for lubrication and electrical motors performance monitoring.

STATEMENT OF WORK:

1. Design a PLC system to be fitted to an electric cable shovel.

2. The PLC system must be equipped to monitor and control the lubrication system as well as the condition of electrical motors, bearings, etc.

3. The PLC system must provide displays of data and condition (lack of grease, unlubricated areas, abnormal temperatures) in the shovel operators cab.

4. The PLC's and associated instrumentation will be installed on two shovels and field tested over a period of four months that spans winter and summer ambient temperatures.

5. Data obtained during the field tests will be evaluated to determine the effectiveness and reliability of the PLC's developed.

6. All of the above will be documented and evaluated in a technical and cost-benefit sense in the final report.

ESTIMATED COSTS:

The direct costs associated with this project relating to the design, fabrication, assembly and testing of PLC's will not exceed $50,000.

The Bullmoose Operating Corporation has agreed to share costs and bear 50% of these direct costs.

The indirect costs associated with this project are estimated to be $40,000 comprising of operator manpower, equipment downtime, running maintenance and provision of data collection and analysis.

Bullmoose Operating Corporation has agreed to bear all of these indirect costs.

SUMMARY OF COSTS: (1989-90)

Direct Costs	$50,000	(Cost to Crown $25,000)
Indirect Costs	$40,000	(Cost to Crown NIL)
TOTAL	$90,000	

APPENDIX B

PLC SHOVEL ALARM LOG BOOKS

2304 SHOVEL ALARM LOG FOR PLC

MAY 23, Nightshift - Upper Spray Fault which resulted in high temperature in Left Swing Motor.

MAY 24, Nightshift - Upper Spray and Upper Lube Fault. Would not reset by holding both buttons. Found high temperature in the Left Shipper Shaft Bearing. High temp. grease was added and it cooled down.

MAY 25, Nightshift - Upper Lube Fault, Reset.

MAY 26, Nightshift - Upper Lube Fault, set upper lube pressure switch lower.

MAY 28, Nightshift - Upper Lube Fault, could not reset alarm so turned pressure switch down again.

JUNE 8, Dayshift - Lower Lube Alarm, no pressure building up, suspect broken grease line.

JUNE 11, Dayshift - Left Hand Swing Motor, over Temp. 52C, wires crossed. Crowd motor running warm, to be checked on next PM.

JUNE 12, Dayshift - Shovel down for PM, all lines checked and alarms clear.

JUNE 17, Dayshift - Lower Lube and Upper Lube Fault, found broken grease lines, repaired.

JUNE 25, Dayshift - Upper Lube Fault, reset and no problem found.

JULY 10, Nightshift - Changed pressure switch for upper spray, Mac valve stuck open blowing lines apart.

JULY 11, Nightshift - Lower Lube Fault, reset.

JULY 24, Dayshift - Lower Lube Fault, broken line.

JULY 27, Nightshift - Pressure switch for lower lube set to 1500 p.s.i. adjusted to 2250 p.s.i.

AUG. 4, Nightshift - Lower Lube Fault, low air pressure.

AUG. 5, Nightshift - Upper Lube Fault, reset.

AUG. 9, Dayshift - Lower Lube Fault, regulator leaking air and grease barrel low.

AUG. 17, Dayshift - Upper Spray Fault, broken grease line.

AUG. 18, Dayshift - Lower Lube Fault, reset.

AUG. 21, Dayshift - Lower Lube Fault, bleeder valve no good.

AUG. 27, Dayshift - Lower Lube Fault, changed program.

SEPT. 10, Dayshift - Lower Lube Fault, injectors bypassing.

OCT. 1, Dayshift - Upper Spray Fault, leak at saddle blocks.

OCT. 5, Nightshift - Upper Spray Fault, pressure switch needed adjusting (was 5300 now 2200 p.s.i.).

OCT. 24, Nightshift - Lower Lube Fault, reset.

NOV. 26, Dayshift - Lower Lube Fault, reset.

NOV. 27, Dayshift - Lower Lube Fault, reset.

DEC. 12, Nightshift - Upper Grease Fault, stuck mac valve.

<u>2303 SHOVEL LOG FOR PLC</u>

SEPT. 28, Dayshift - Upper Spray Fault, mac valve sticking.

NOV. 27, Nightshift - Lower Lube Fault, not building up to pressure.

JAN. 25, Dayshift - Upper Spray Fault, low grease in barrel.

JAN. 25, Nightshift - Lower Lube Fault, reset pressure switch to 2250 p.s.i. Also, leak at four way valve.

JAN. 29, Nightshift - Upper Spray Fault, air leaks repaired.

all of these systems are in place the monitoring functions will be expanded to include problematic areas of the shovel.

The electrical control circuits on the P&H shovels are difficult to debug and at times many hours are spent locating the problem. It would be beneficial to monitor the solid state motion control circuits in order to reduce trouble shooting time. This will be one of the areas included in the expansion of the monitoring functions of the PLC.

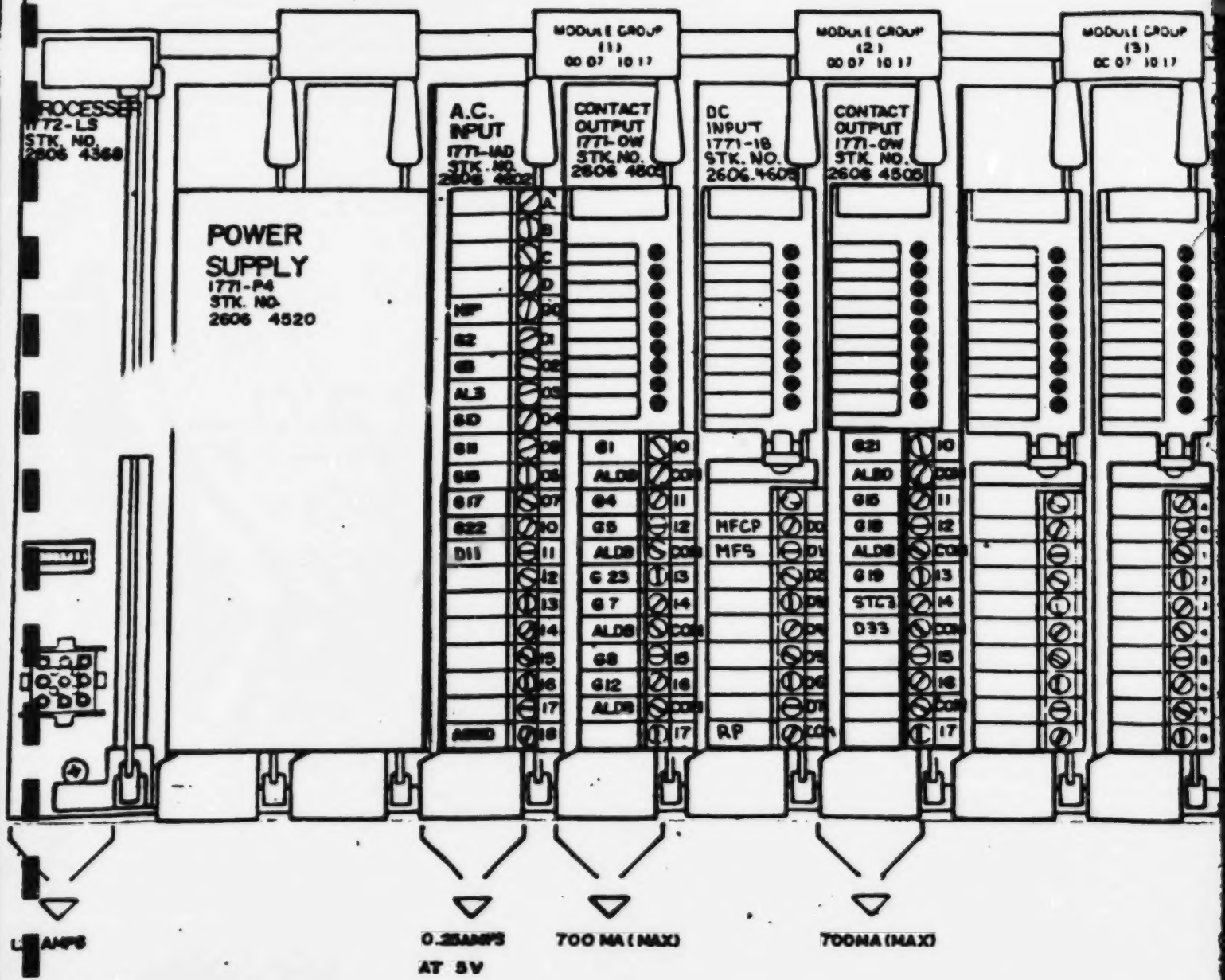
The shunt field trip monitoring and control function has been added to all of the shovels. The problem is a result of the P&H control frame and this is an effective way to ensure that motor fields do not overheat and become damaged.

Also, a small printer may be installed in the operators cab on all if the shovels so that a hard copy of all faults can be obtained.

3.4.2 Drills

Future projects include adding a PLC to the blasthole drills. The PLC would monitor drilling parameters (pulldown, rotation) which is expected to extend the life of motors and bits. The PLC would also monitor major components and motors to aid in trouble shooting. This would increase the availability and reliability of the drills.

FIGURE ONE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MODULE GROUP (3) 00 07 10 17
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POWER SUPPLY 1771-P4 STK. NO. 2606 4520
A.C. INPUT 1771-IAD STK. NO. 2606 4502
CONTACT OUTPUT 1771-OW STK. NO. 2606 4503
DC INPUT 1771-ID STK. NO. 2606 4609
CONTACT OUTPUT 1771-OW STK. NO. 2606 4503
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RP
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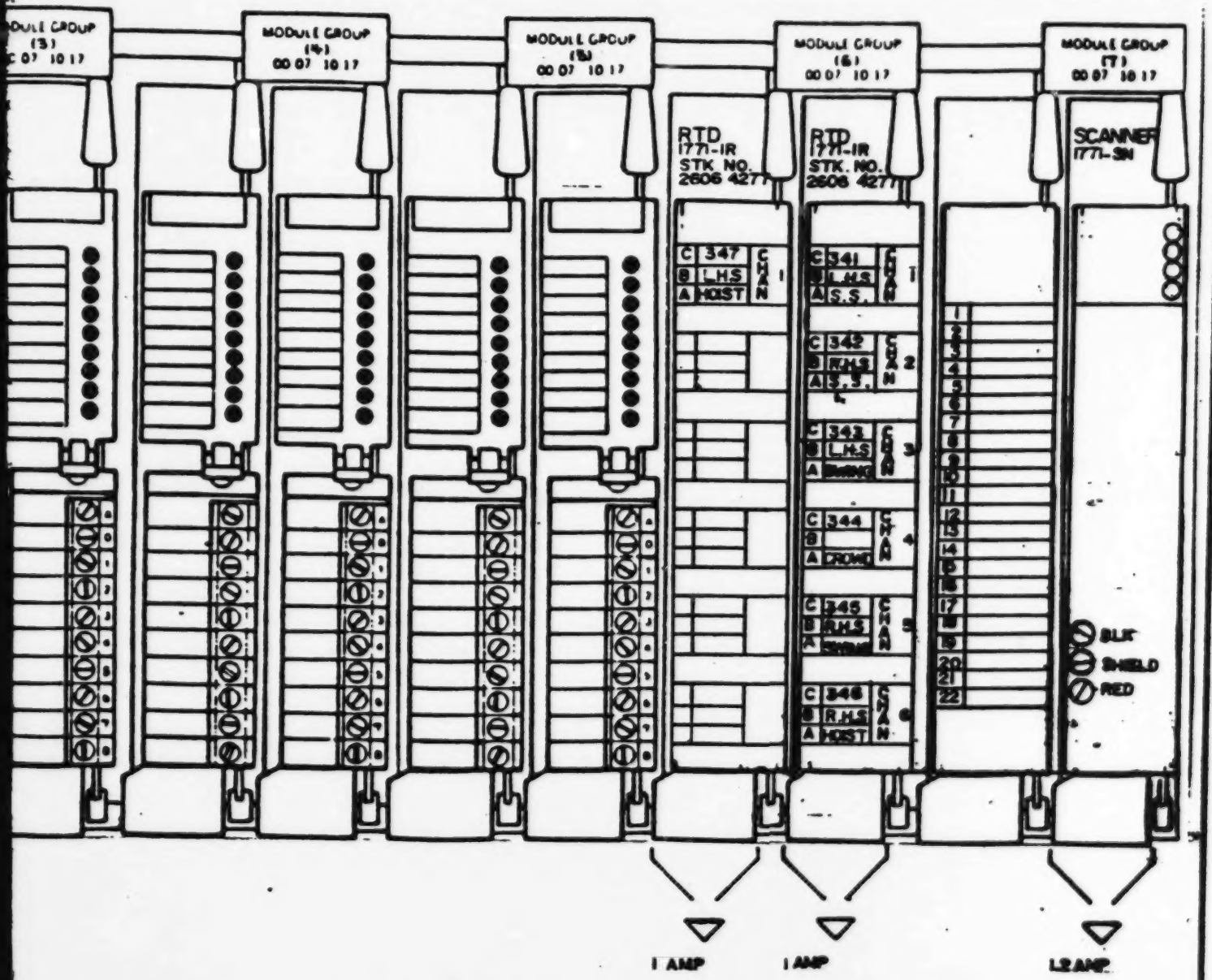
700MA (MAX)

ONE

RACK LOAD= AMPS
LOCATION
CHANNEL



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2	89/11/20	RTD	WP
1	88/8[illegible]	REVISION	WP

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BULLMOOSE OPERATING CORP.

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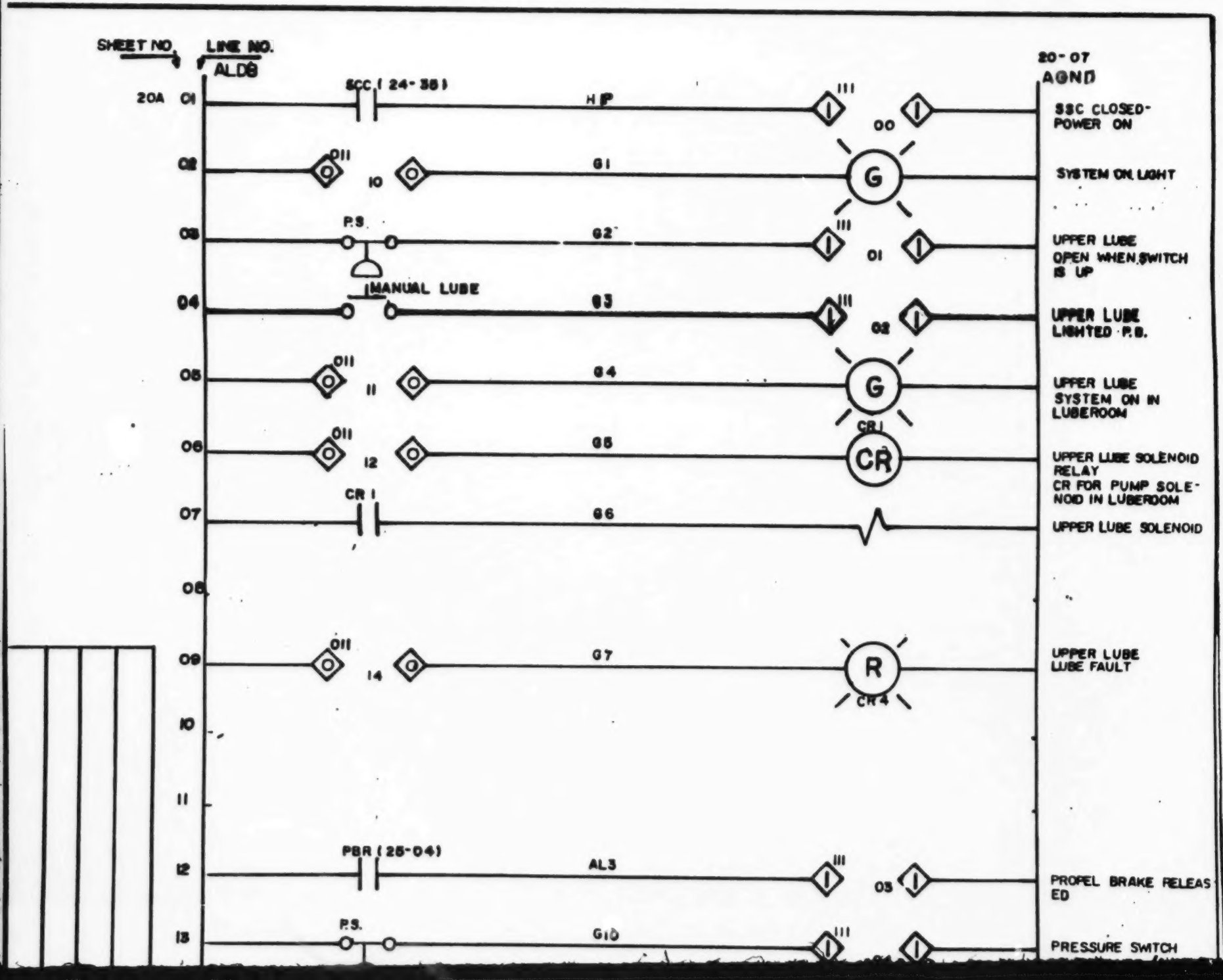
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LINE NO.
ALD8
20A 01
SCC (24-38)
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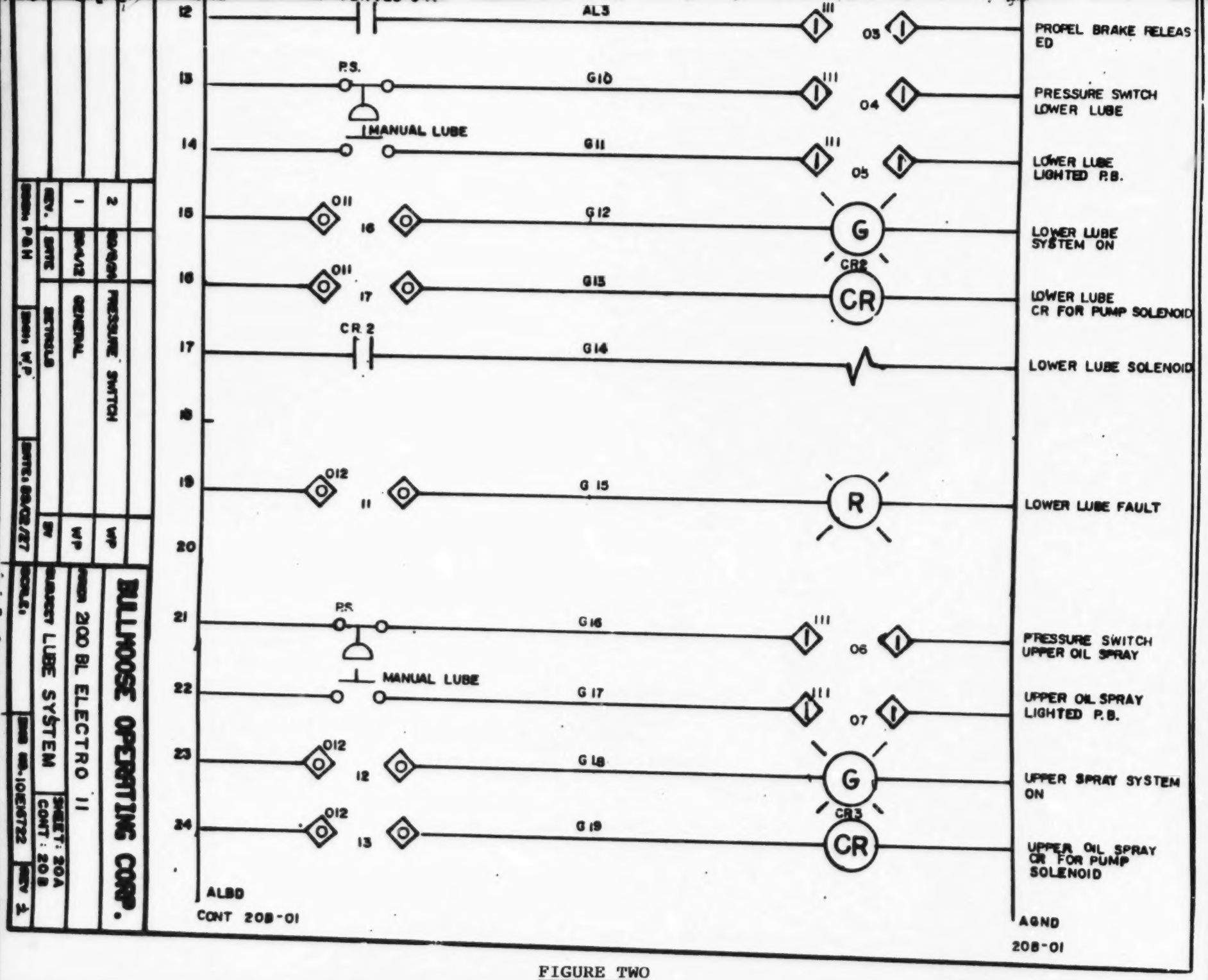
00
20-07
AGND
SSC CLOSED-POWER ON
02
011
10
G1
G
SYSTEM ON LIGHT
03
P.S.
G2
111
01
UPPER LUBE OPEN WHEN SWITCH IS UP
04
MANUAL LUBE
G3
111
02
UPPER LUBE LIGHTED P.B.
05
011
11
G4
G
UPPER LUBE SYSTEM ON IN LUBEROOM
06
011
12
G5
CR1
CR
UPPER LUBE SOLENOID RELAY
CR FOR PUMP SOLENOID IN LUBEROOM
07
CR1
G6
UPPER LUBE SOLENOID
08
09
011
14
G7
R
CR4
UPPER LUBE LUBE FAULT
10
11
12
PBR (25-04)
AL3
111
03
PROPEL BRAKE RELEASED
13
P.S.
G10
111
PRESSURE SWITCH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AL3
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PROPEL BRAKE RELEASED
13
P.S.
G10
111
04
PRESSURE SWITCH LOWER LUBE
MANUAL LUBE
14
G11
111
05
LOWER LUBE LIGHTED P.B.
15
011
16
G12
G
LOWER LUBE SYSTEM ON
CR2
16
011
17
G13
CR
LOWER LUBE CR FOR PUMP SOLENOID
CR 2
17
G14
LOWER LUBE SOLENOID
18
19
012
11
G 15
R
LOWER LUBE FAULT
20
21
P.S.
G16
111
06
PRESSURE SWITCH UPPER OIL SPRAY
MANUAL LUBE
22
G 17
111
07
UPPER OIL SPRAY LIGHTED P.B.
23
012
12
G 18
G
UPPER SPRAY SYSTEM ON
CR3
24
012
13
G 19
CR
UPPER OIL SPRAY OR FOR PUMP SOLENOID
ALBD
CONT 208-01
AGND
208-01
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POWER 200 BL ELECTRO II
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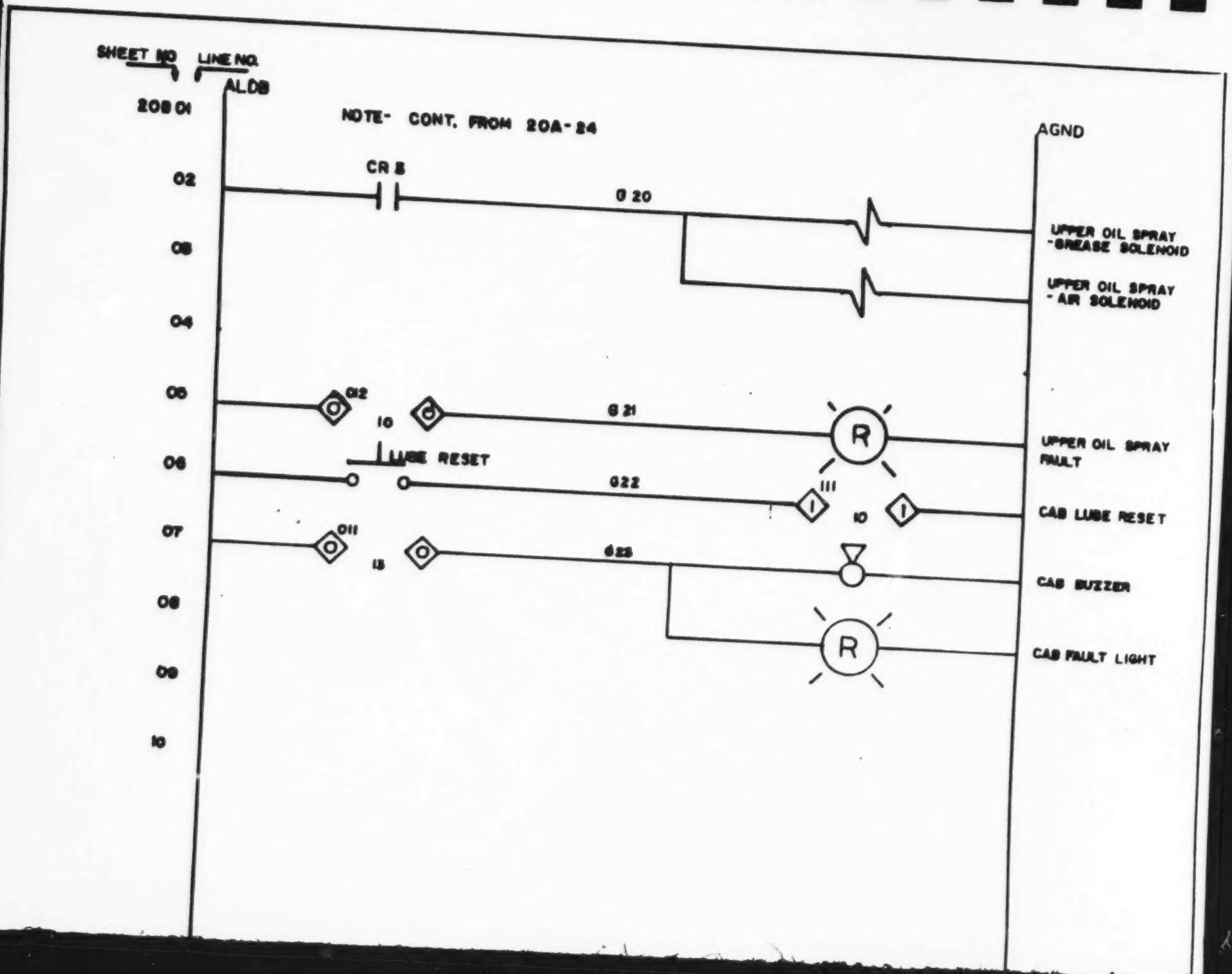
DRAWN P&H
CHKD. W.P.
DATE: 08/02/87
BY WP
REV. 1
2

FIGURE TWO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AGND
02
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04
05
012
10
G 21
R
UPPER OIL SPRAY FAULT
06
LUBE RESET
G22
111
1
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CAB LUBE RESET
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011
13
G23
CAB BUZZER
08
R
CAB FAULT LIGHT
09
10

AGND

FIGURE TWO CONT'D

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BULLMOOSE OP. CORP.

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SUBJECT LUBE SYSTEM

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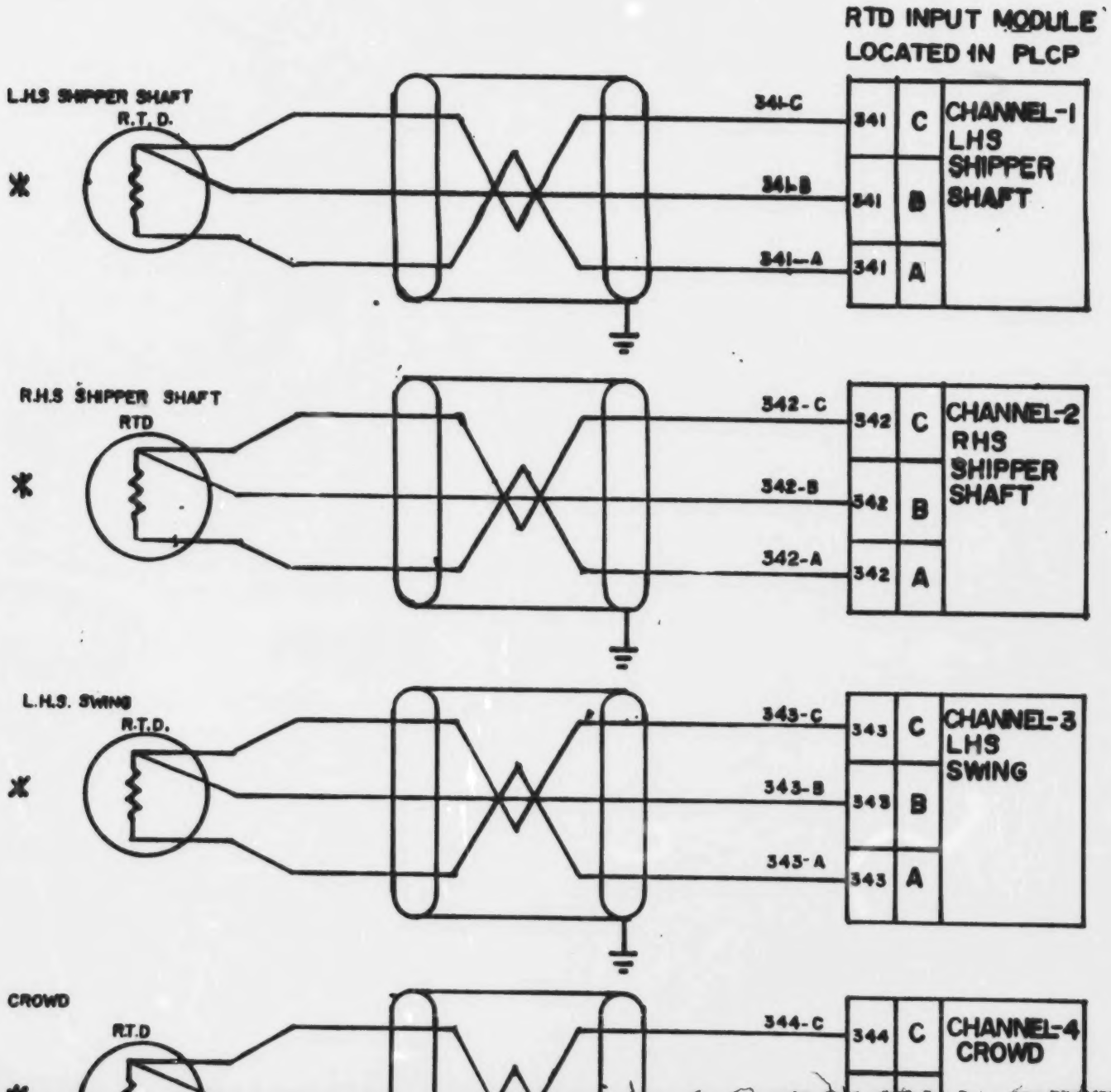
RTD INPUT MODULE
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L.H.S SHIPPER SHAFT
R.T.D.
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341-B
341-A
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341 A
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LHS
SHIPPER
SHAFT
R.H.S SHIPPER SHAFT
RTD
342-C
342-B
342-A
342 C
342 B
342 A
CHANNEL-2
RHS
SHIPPER
SHAFT
L.H.S. SWING
R.T.D.
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CROWD
R.T.D
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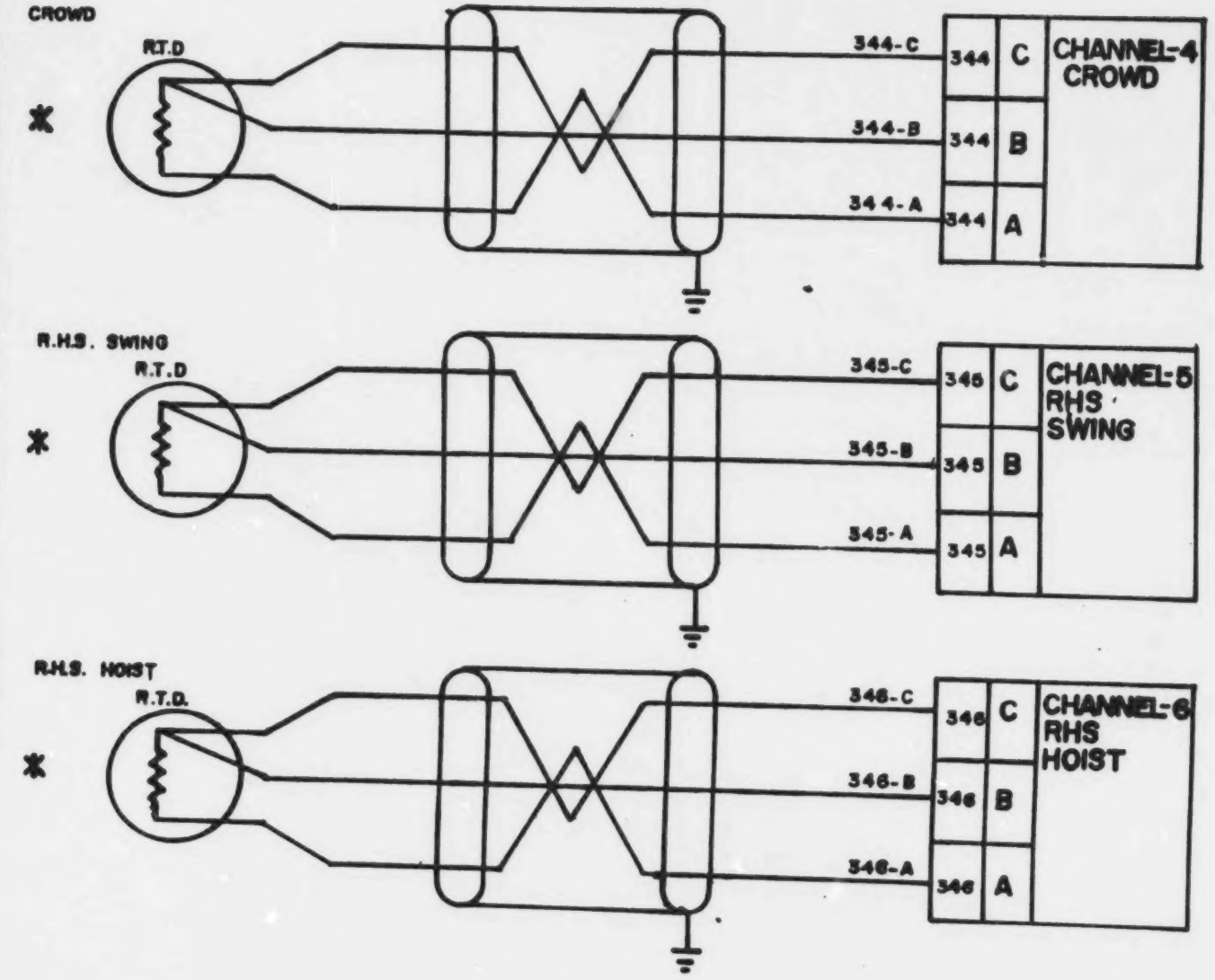
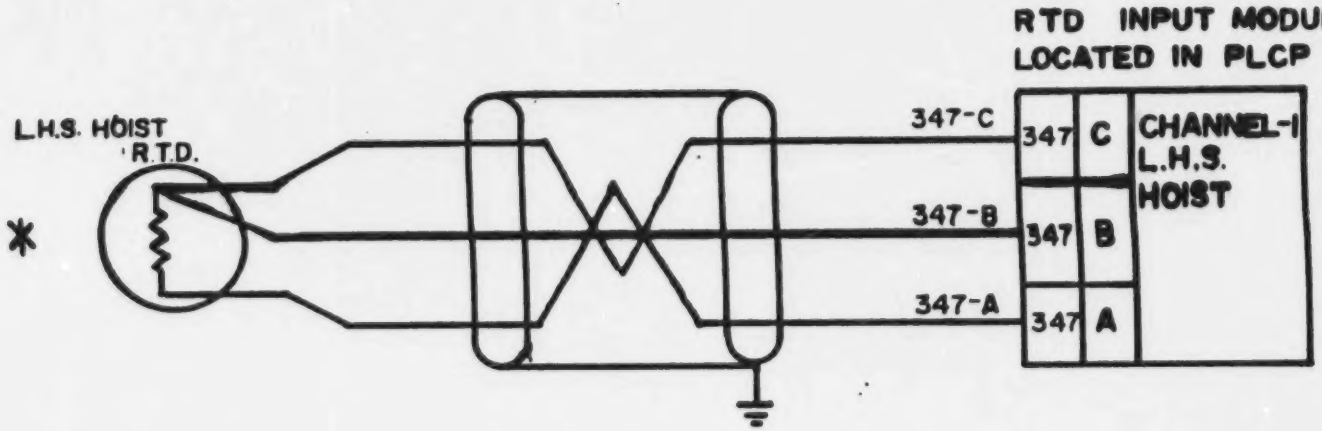
344 C
CHANNEL-4
CROWD



NOTE:
R.T.D. STOCK NO. 2805-4154

BULLMOOSE OP. CORP.
AREA: 2100 EL. ELECTRO II
SUBJECT: RESISTANCE TEMP. DEVICE
SCALE: /
SHEET: 200
REV 0
DRWN: BDC
DWN: WP
DATE: 08/08/78
REV. | DATE | DETAILS | BY

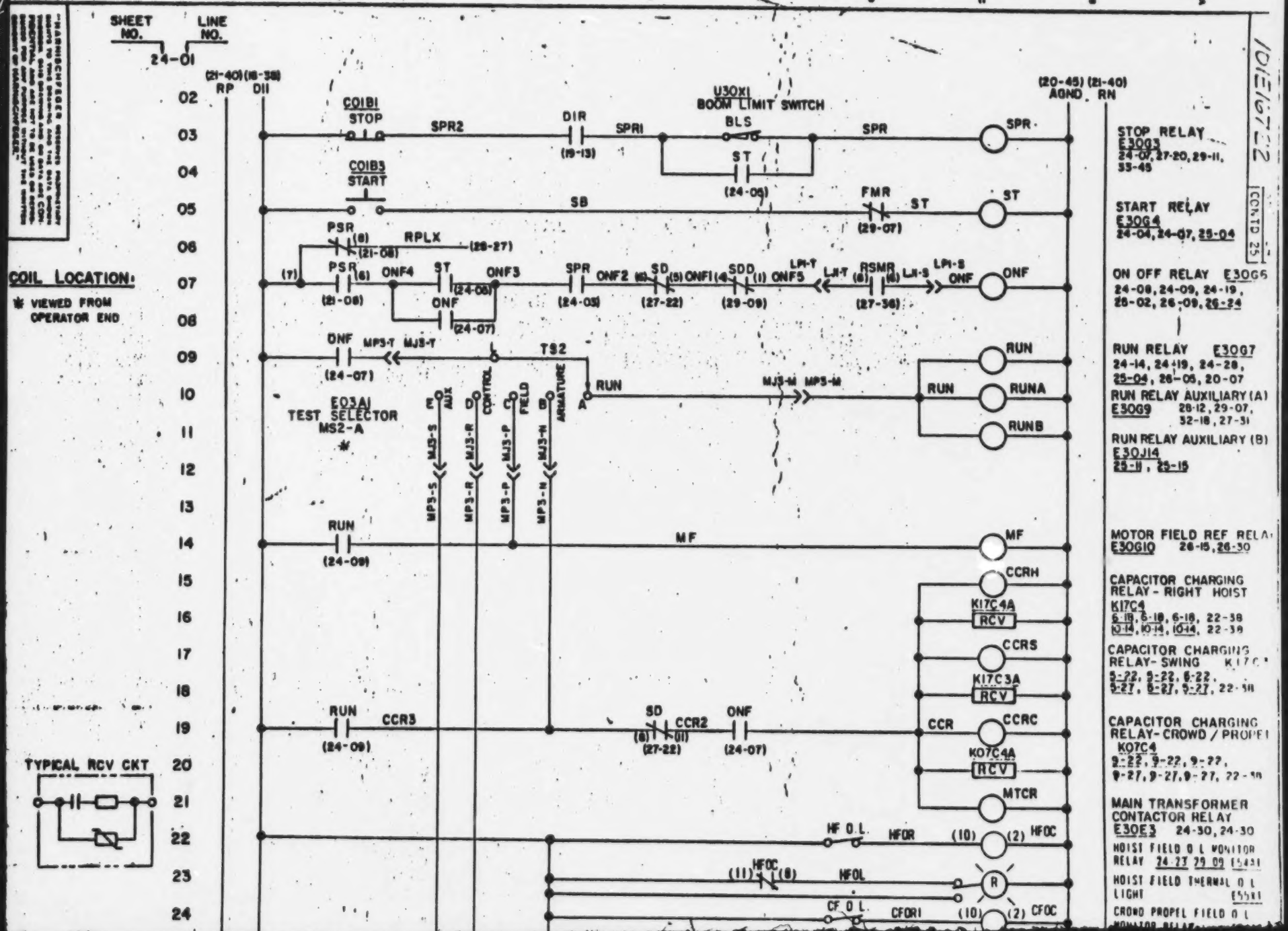
FIGURE THREE



NOTE:
R.T.D. STOCK NO. 2605 - 4154

FIGURE THREE CONT'D

					BULLMOOSE OP. CORP.	
					AREA: 2100 ELECTRO II	
	REV	DATE	DETAILS	BY	SUBJECT · RESISTANCE TEMP. DEVICE	
	DSGN S.O.C	DWN · WP	DATE 89/11/21		SCALE	SHEET: 20E REV O


SHEET NO.
LINE NO.
24-01
(21-40) (18-38)
RP DII
(20-45) (21-40)
AGND RN
COIBI
STOP
SPR2
DIR
(19-13)
SPRI
U30XI
BOOM LIMIT SWITCH
BLS
SPR
ST
(24-05)
SPR
COIB3
START
SB
FMR
(29-07)
ST
PSR
(8)
(21-08)
RPLX
(28-27)
(7)
PSR
(6)
(21-08)
ONF4
ST
(24-05)
ONF
(24-07)
ONF3
SPR
(24-05)
ONF2
(6)
SD
(5)
(27-22)
ONF1
(4)
SDD
(1)
(29-09)
ONF5
LPI-T
LJI-T
(6)
RSMR
(8)
LJI-S
LPI-S
ONF
ONF
(24-07)
MPS-T
MJ3-T
TS2
RUN
(24-07)
E03AI
TEST SELECTOR
MS2-A
E
AUX
D
CONTROL
C
FIELD
B
ARMATURE
A
RUN
MJ3-S
MJ3-R
MJ3-P
MJ3-N
MJ3-M
MPS-M
RUN
RUNA
RUNB
RUN
(24-09)
MF
MF
CCRH
K17C4A
RCV
CCRS
K17C3A
RCV
RUN
(24-09)
CCR3
SD
(8)
(27-22)
CCR2
(11)
ONF
(24-07)
CCR
CCRC
K07C4A
RCV
MTCR
HF O.L.
HFOR
(10)
(2) HFOC
HFOC
(11)
(8)
HFOL
R
CF O.L.
CFOR1
(10)
(2) CFOC
TYPICAL RCV CKT
COIL LOCATION:
* VIEWED FROM OPERATOR END
STOP RELAY E3003
24-07, 27-20, 29-11, 33-45
START RELAY E30G4
24-04, 24-07, 25-04
ON OFF RELAY E30G6
24-08, 24-09, 24-19, 25-02, 26-09, 26-24
RUN RELAY E30G7
24-14, 24-19, 24-28, 25-04, 26-05, 20-07
RUN RELAY AUXILIARY (A) E30G9
28-12, 29-07, 32-18, 27-31
RUN RELAY AUXILIARY (B) E30J14
25-11, 25-15
MOTOR FIELD REF RELAY E30G10
26-15, 26-30
CAPACITOR CHARGING RELAY - RIGHT HOIST K17C4
6-18, 6-18, 6-18, 22-38
10-14, 10-14, 10-14, 22-39
CAPACITOR CHARGING RELAY - SWING K17C3
9-22, 9-22, 9-22, 9-27, 9-27, 9-27, 22-38
CAPACITOR CHARGING RELAY - CROWD / PROPEL K07C4
9-22, 9-22, 9-22, 9-27, 9-27, 9-27, 22-38
MAIN TRANSFORMER CONTACTOR RELAY E30E3
24-30, 24-30
HOIST FIELD O L MONITOR RELAY
24-23 29-09 E5431
HOIST FIELD THERMAL O L LIGHT E5581
CROWD PROPEL FIELD O L MONITOR RELAY
10E167-2 CONTD 25

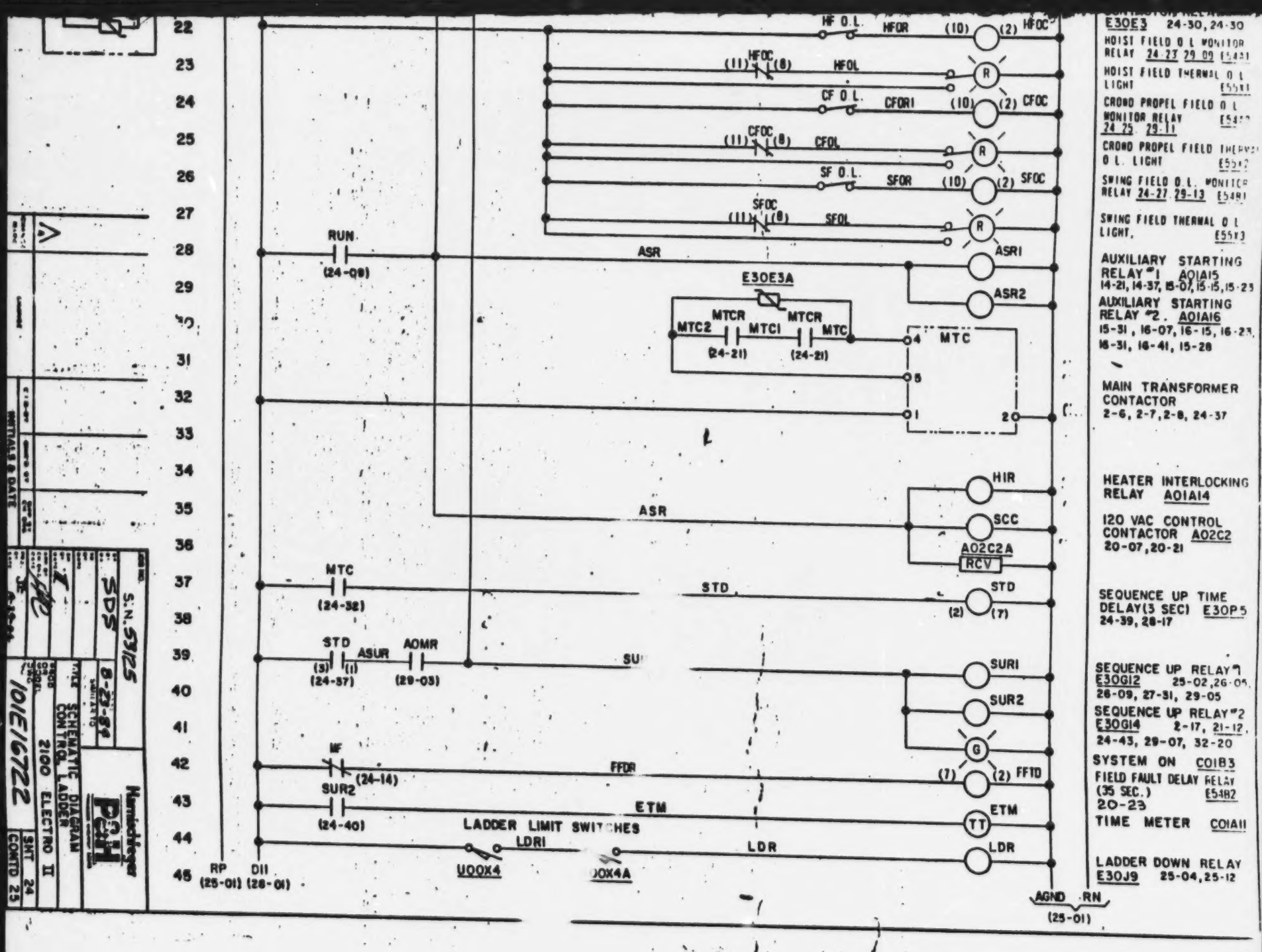
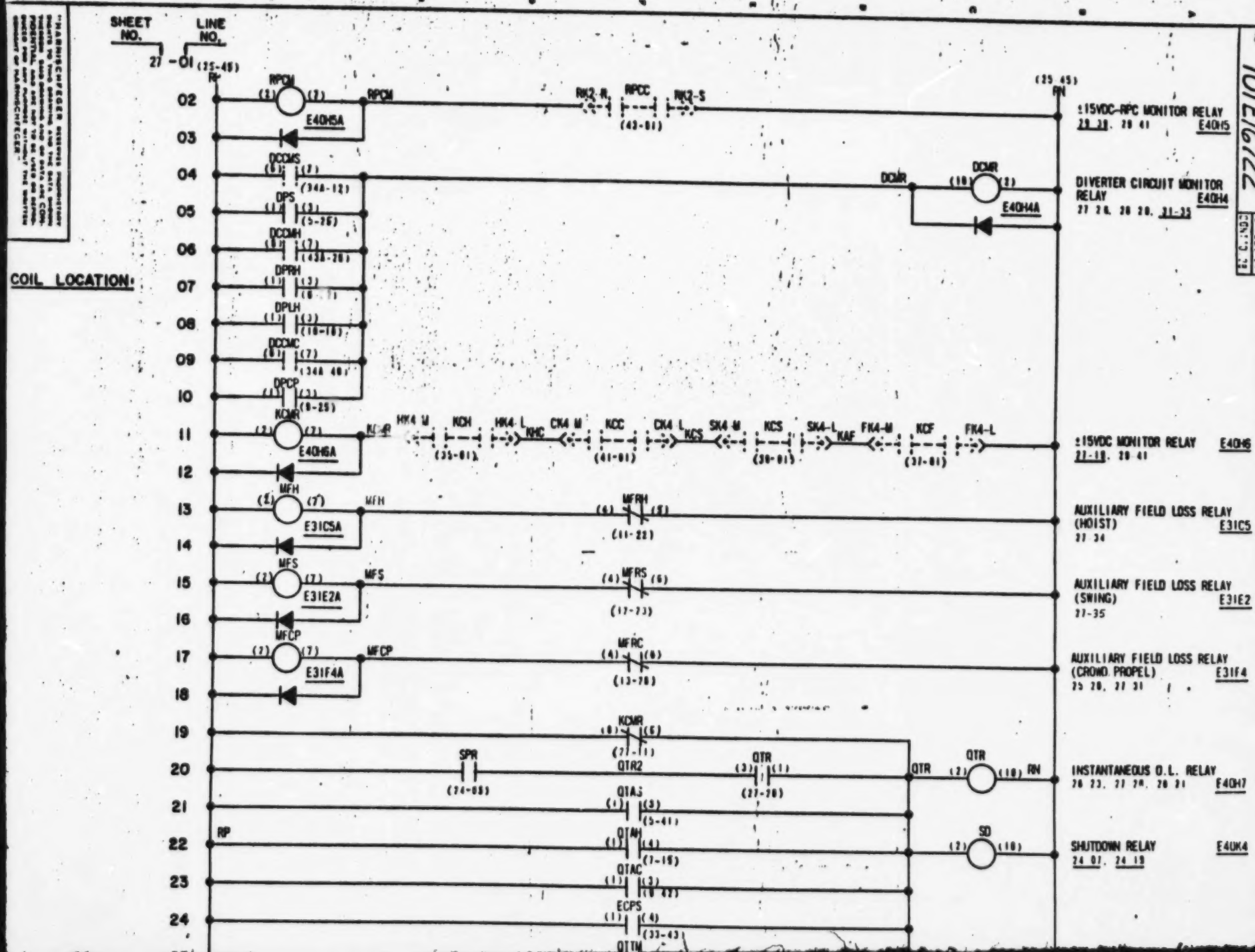

HF O.L.
HFOR
(10)
(2) HFOC
HFOC
(11)
(8)
HFOL
R
CF O.L.
CFOR
(10)
(2) CFOC
CFOC
(11)
(8)
CFOL
R
SF O.L.
SFOR
(10)
(2) SFOC
SFOC
(11)
(8)
SFOL
R
RUN
(24-09)
ASR
ASRI
ASR2
E30E3A
MTC2
MTCR
MTC1
MTCR
MTC
(24-21)
(24-21)
4
MTC
5
1
2
HIR
ASR
SCC
A02C2A
RCV
MTC
(24-32)
STD
STD
(2)
(7)
STD
(3)
(24-37)
ASUR
(1)
AOMR
(29-03)
SU
SURI
SUR2
G
MF
(24-14)
FFDR
(7)
(2) FFTD
SUR2
(24-40)
ETM
ETM
TT
LADDER LIMIT SWITCHES
LDRI
U00X4
00X4A
LDR
LDR
RP
(25-01)
DII
(28-01)
AGND
RN
(25-01)
E30E3 24-30, 24-30
HOIST FIELD O L MONITOR RELAY 24-27 29-09 E5481
HOIST FIELD THERMAL O L LIGHT E55X1
CROWD PROPEL FIELD O L MONITOR RELAY E5482 24-25 29-11
CROWD PROPEL FIELD THERMAL O L LIGHT E55X2
SWING FIELD O L MONITOR RELAY 24-27 29-13 E5483
SWING FIELD THERMAL O L LIGHT. E55X3
AUXILIARY STARTING RELAY #1 A01A15 14-21, 14-37, 15-07, 15-15, 15-25
AUXILIARY STARTING RELAY #2. A01A16 15-31, 16-07, 16-15, 16-23, 16-31, 16-41, 15-28
MAIN TRANSFORMER CONTACTOR 2-6, 2-7, 2-8, 24-37
HEATER INTERLOCKING RELAY A01A14
120 VAC CONTROL CONTACTOR A02C2 20-07, 20-21
SEQUENCE UP TIME DELAY(3 SEC) E30P5 24-39, 28-17
SEQUENCE UP RELAY #1 E30G12 25-02, 26-05, 26-09, 27-31, 29-05
SEQUENCE UP RELAY #2 E30G14 2-17, 21-12, 24-43, 29-07, 32-20
SYSTEM ON C01B3
FIELD FAULT DELAY RELAY (35 SEC.) E5482 20-23
TIME METER C01A11
LADDER DOWN RELAY E30J9 25-04, 25-12
SCHEMATIC DIAGRAM CONTROL LADDER
2100 ELECTRO II
SHT 24 CONTD 25
101E16722
S.N. 5125
SDS
8-23-84

FIGURE FOUR


SHEET NO.
LINE NO.
27 - 01 (25-45)
COIL LOCATION:
RPCM
E40H5A
RK2-R
RPCC
(43-01)
RK2-S
(25 45) RN
±15VDC-RPC MONITOR RELAY E40H5
DCCMS
(348-12)
DPS
(5-26)
DCCMH
(428-26)
DPRH
DPLH
(18-18)
DCCMC
(348 48)
DPCP
(8-25)
DCMR
E40H4A
DIVERTER CIRCUIT MONITOR RELAY E40H4
KCMR
E40H6A
HK4-M
KCH
(35-01)
HK4-L
KHC
CK4-M
KCC
(41-01)
CK4-L
KCS
SK4-M
(38-01)
SK4-L
KAF
FK4-M
KCF
(31-01)
FK4-L
±15VDC MONITOR RELAY E40H6
MFH
E31C5A
MFRH
(11-22)
AUXILIARY FIELD LOSS RELAY (HOIST) E31C5
MFS
E31E2A
MFRS
(17-23)
AUXILIARY FIELD LOSS RELAY (SWING) E31E2
MFCP
E31F4A
MFRC
(13-78)
AUXILIARY FIELD LOSS RELAY (CROWD PROPEL) E31F4
SPR
(74-05)
QTR2
QTR
(27-28)
INSTANTANEOUS O.L. RELAY E40H7
QTAJ
(5-41)
QTAH
(7-15)
SD
SHUTDOWN RELAY E40K4
QTAC
ECPS
(33-43)
QTTM
RP
RN

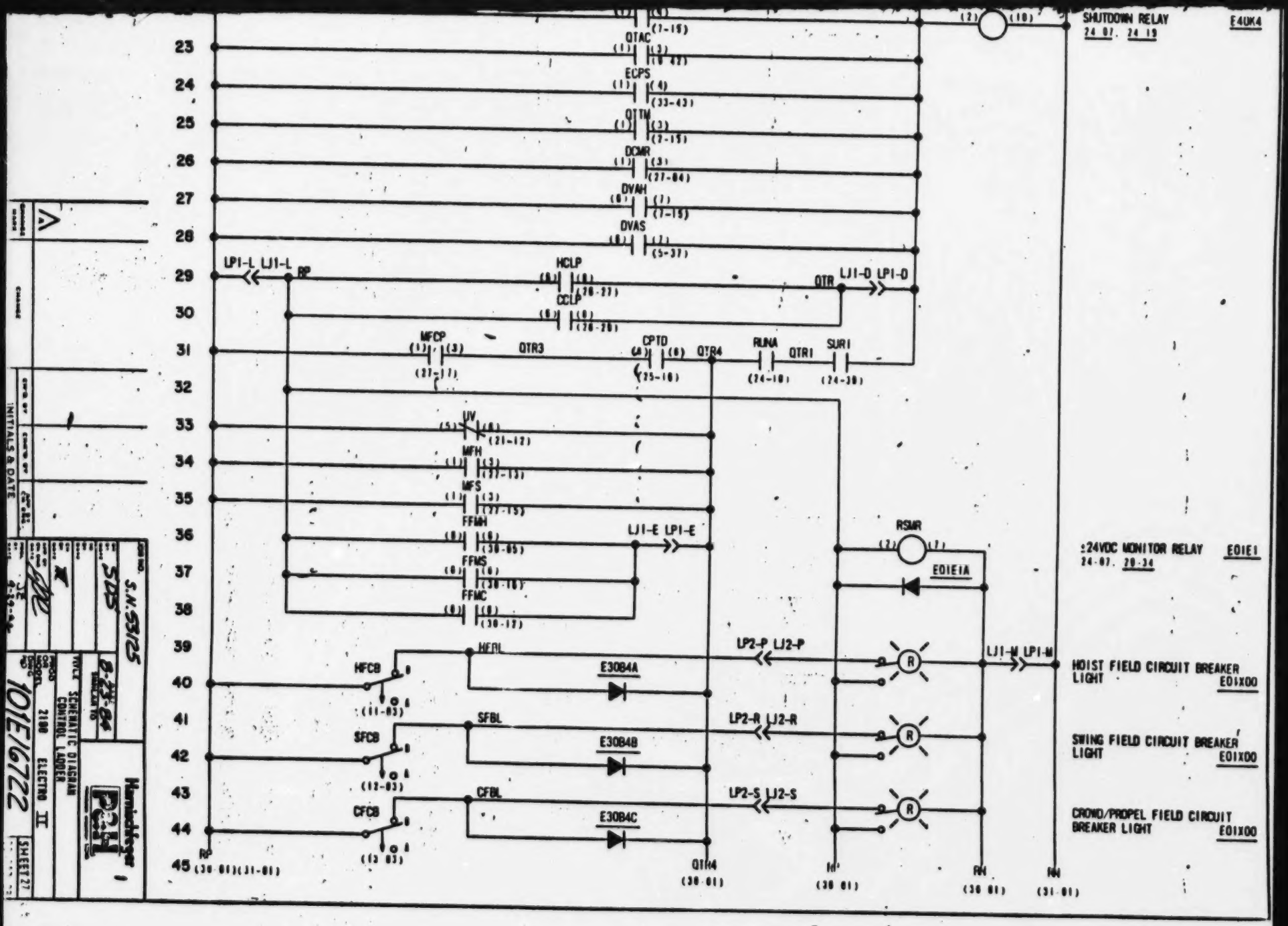
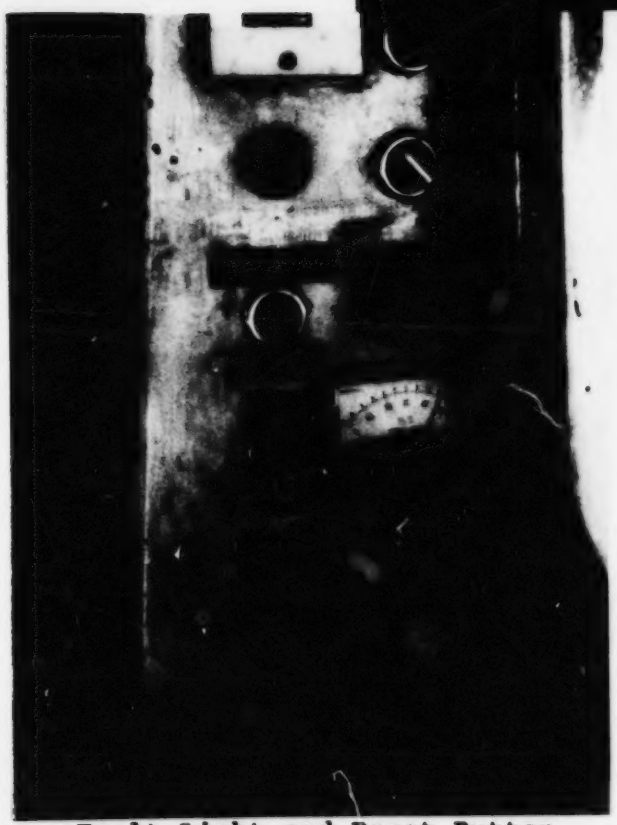


FIGURE FOUR CONT'D

Programming in
Electrical Shop



Fault Light and Reset Button
in Shovel Operator's Cab

Figure Five

Close-up of Plasma
Display

Plasma Display in Shovel
Operators's Cab

Figure Five
(continued)